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Does the unusual geochemical composition of the São Francisco basin natural gas (E Brazil) reveal typical characteristics of ancient and overmature petroleum systems?

HUMBERTO L. S. REIS[1] AND RENATO CESAR SALGADO FONSECA[2]

[1]Geology Department, Universidade Federal de Ouro Preto (UFOP)

[2]Wintershall Dea do Brasil E&P Ltda

Presenting Author: humberto.reis@ufop.edu.br

The geochemical composition of the natural gas in sedimentary basins may vary according to: i) the age, composition and thermal maturity of source rocks, ii) oil and gas cracking-derived inputs, iii) different mixture trends between thermogenic, biogenic and abiogenic compounds, among others. Recent hydrocarbon exploration in the São Francisco basin of E Brazil has revealed different aspects of one of the oldest known gas-prone and unconventional petroleum systems, which reached its main climax during the Ediacaran-Ordovician Brasiliano/Pan-African West Gondwana assembly. The natural gas occurrences of the basin are hosted by Proterozoic to Cambrian tight sandstones and carbonates and fractured mudstone reservoirs, and comprise typical dry gases with $C_1/(C_2+C_3)$ ratios ranging mostly from 10 to 400. Lacking CO_2 and H_2S, they exhibit variable concentrations of N_2, traces of H_2 and up to c. 1,5 % of He. The light hydrocarbon concentrations and $\delta^{13}C$ and $\delta^{2}H$ isotopic contents indicate different mixtures between biogenic and thermogenic compounds, as well as unusually depleted $\delta^{2}H_{C1}$ signatures. Available data suggest that these hydrocarbons were partially sourced by Mesoproterozoic and post-glacial Ediacaran overmature source rocks. In the easternmost São Francisco basin, concentrations of up to c. 40% by vol. of H_2 have been identified within methane-rich and He-bearing gases in overpressured to normal pressured Ediacaran-Cambrian fractured reservoirs. The stable isotopic contents of these gases and new data acquired during recent researches indicate an important contribution of abiotic processes[1][2]. Crustal abiotic gas sources seem to have been connected with the shallower petroleum system by deep-seated structures partially inverted during the Brasiliano/Pan-African orogenies. The unusual geochemical composition of the São Francisco basin natural gas apparently record the combination of i) a long-term and complex geological history typical of ancient intracratonic basins, ii) an overmature petroleum system, iii) and the mixture between biogenic, thermogenic and abiotic compounds over a wide time interval. Besides illustrating the challenges on exploring ancient petroleum systems, the São Francsico basin natural gas also reveals possible economic upsides and the potential for other clean energy resources in Precambrian frontier sedimentary basins.

[1]Flude et al. (2019) AGU Fall Meeting.

[2]Sherwood Lollar et al. (2002) Nature 416: 522-524.